# Wisconsin Highway Research Program

## Analysis of Trends and Correlations of Historical WisDOT Soil Laboratory Results Through Development of an Electronic Database

Wisconsin Highway Research Program
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**University of Wisconsin-Platteville**
**March 3, 2010**

# <u>Summary Page</u>

**Project Title:** Analysis of Trends and Correlations of historical WisDOT Soil Laboratory Results Through Development of an Electronic Database

**Proposing Agency:** University of Wisconsin-Platteville, 1 University Plaza, Platteville, WI, 53818

**Person Submitting the Proposal:** Mark S. Meyers, PhD, PE, Department of Civil & Environmental Engineering

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**Proposal Date:** March 3, 2010

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**Administrative Officer:** Provost Duane Ford, University of Wisconsin-Platteville, 1 University Plaza, Platteville, WI, 53818

**Proposed Contract Period:** 24 months

**Total Contract Amount:** $63,951

**Indirect Cost Portion at:** 16 percent

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## Analysis of Trends and Correlations of Historical WisDOT Soil Laboratory Results Through Development of an Electronic Database

### Background

The Wisconsin Department of Transportation (WisDOT) will continue to build, maintain, and rehabilitate existing transportation facilities similar to what has been done in the past. For much of this work, the underlying soil characteristics do not change over time, especially in a given project area. Over the years, WisDOT has performed many laboratory tests on soil samples collected for the design and construction of these various transportation facilities located throughout the state. Generally, these laboratory test results are in paper format, which does not allow for easy retrieval of the data or for analysis of trends or correlations between records. As such, there appears to be a large benefit from organizing the lab test results data into an electronic database that can be easily searched and analyzed for use on future WisDOT projects. Development of this database and analysis of the associated trends and correlations will allow future designers to review this past information, which will be very useful during the planning and early design stages, as well as later in the project when developing subsurface investigation programs.

### Objectives

The objectives of this project are twofold:

a. To create an electronic database of WisDOT soil laboratory testing results that will be linked to a Geographic Information System (GIS) to allow for searching WisDOT project related records by spatial location, which will facilitate the planning of geotechnical explorations and provide geotechnical data for planning and design of transportation facilities.

b. To analyze the data in the database for trends and correlations relating to location, soil type, soil classification, geologic source, index properties, structural design values, etc., and to compare the trends to typical published values for respective soil types.

### Detailed Work Plan

The objectives of the project will be accomplished based on a work plan consisting of seven primary tasks: Literature Review; Data Collection and Review; Database Design and Development; GIS Design and Linkage to the Database; Provisioning the Database; Analysis of the Collected Data Using the Database; and Reporting.

#### Task 1: Literature Review

The objective of Task 1 is to identify, collect, review, and synthesize literature to understand existing state and national practices involving soils and geotechnical engineering related database platforms. Recent informal discussions with colleagues indicate that Iowa State University may have developed a similar database for the Iowa DOT and the State of Minnesota is developing a similar database.

The database platforms will be examined with respect to structure, input and output formats, software and hardware requirements, and data integration issues with non-geotechnical databases such as construction, design, and performance. According to Schmitt and Owusu-

Ababio (2007), the major databases for Wisconsin highway pavements include Meta-manager, construction, design, and performance. Meta-Manager is a comprehensive integrated database system for conducting needs and performance analyses for pavements and bridges. It is comprised of independent databases organized by region for all five regions in Wisconsin. Each region consists of one Excel spreadsheet workbook with multiple datasheets, as well as, ArcGIS shape files and Arclnfo GIS coverage files that can be used for geographic analysis. The workbook datasheets include information on base, roadway, unimproved pavement condition, improved pavement condition, safety, pavement treatment scoping, mobility, unimproved bridge condition, and improved bridge condition. The mobility and roadway datasheets contain projected traffic volume data. Both datasheets identify pavement segments using sequence numbers, traffic segment identification numbers, and from-and-to reference points. Other relevant fields include highway number by direction, projected 2-way AADT, and percent trucks for 1, 5, 10, 15, and 20-year periods from a base year.

The construction database consists of Microsoft Excel spreadsheets organized by year with two key files, a design/test log file and a mix design data file. The design/test log file contains more than 2,000 records that show fields representing the highway type (STH, local, CTH, etc.), highway number or letter, surface year, aggregate sources, project location (by descriptive start and end points), county, district, project identification number, contractor, PREfix, test number, and mix type. The mix design data file shows mix design data for more than 2,400 records. The mix design data is organized under fields such as %AC, %VMA, aggregate size distribution in mix, %RAP, Gse, Gsb, Gmm, Gmb, dryback correction, flow, stability, TSR, blows, anti-strip agent, and asphalt cement characteristics (type, source, specific gravity).

The design database is a set of Microsoft Access applications organized by year. Each file has two key tables, namely, *ACOffice* and *ACField*. The A*Coffice* table shows pavement location (rural or urban, district, county, termini by descriptive start and end points), construction style (reconstruction, resurfacing, rehabilitation), contract identification numbers (*contract1, contract2*), project length, pavement surface thickness (*Pvtthick*), milling depth, base type (DGBC, CABC, OGBC2), pavement surface paved over (*Pvdovr*), flexible pavement type, surface year (*pvmntyr*), *mix type denoted by HvMvLv*, case type (Standard, Superpave, SMA, AC Warranty), and design ESAL magnitude. The *ACField* table has show fields representing site identification number (site), sequence number (*Sqno*), beginning reference point (RP), contract identification number *(contract2*), highway name by direction, survey length (Survlen), lane, direction, Asphalt or PCC, set value, measured IRI, and rut depth (Rut) immediately after construction.

The performance database is a Microsoft Access™ application, commonly referred to as the pavement information (PIF) file. It contains pavement inventory and condition data and has various customized forms to facilitate data entry. In addition, it has several tables that summarize the data. The key tables include the descriptive (DESC), pavement distress index (PDI) history file, and International Roughness Index (IRI) data. The descriptive table identifies pavement segments by sequence numbers, county name, county number, district, from-to reference points, from feature, highway number, highway direction, functional class number, national highway system designation, surface year and original construction year. In addition, the table has fields for the segment length, cumulative mileage, and roadbed soil type. The IRI table contains more than 150,000 records representing segments tested between 1980 and 2005. The table lists fields representing the sequence number, inverse year, day-month-year segment was tested, the surface year, surface type, air temperature, average values for IRI, PSI, and Rut. In addition, it lists the speed at which tests were conducted.

The PDI history table has more than 65,000 records. It lists the segment sequence number, inverse year, test day-month-year, surface year, distress type severity and extent for quantifying PDI.

Integration of information from disparate databases such as described above and the proposed soil laboratory testing results database will require that semantic discrepancies within and between databases be identified and alleviated. In addition, key fields must be identified within and across the databases to enable simple or complex queries to be performed in order to relate data residing in the different databases. Common institutional issues involved in the implementation and use of the system will be documented. The literature search will be expedited using electronic search engines.

Task 2: Data Collection and Review

Each of the nine WisDOT offices and the Statewide Geotechnical Office has paper copies of several hundreds of laboratory test results that will need to be entered into the new database. A research team member will travel to each of these locations to scan the laboratory test results information for use in provisioning the database. The scanned versions of the test results will also be included in the database in case a database user wants to review the details of specific tests.

Task 3: Database Design and Development

The design and development of a database system involves an understanding of several elements including the overall purpose of the system, data types and formats to be collected and managed, software and hardware requirements, relations with external databases, as well as institutional issues involved in the implementation and use of the system. The Soil Lab Test (SoLAT) database system to be developed cannot be treated in isolation. Its potential relationship with other databases is depicted in the framework shown as Figure 1. Soil data is a significant input in almost every aspect of highway infrastructure. Soil information is pertinent in the structural design of pavements. In geometric design, soil/geological data is critical to alignment location. In construction, soil data can dictate equipment selection and construction cost. In maintenance and rehabilitation of pavement structures, soil information provides some clues regarding the appearance of certain pavement distresses and the overall performance of the pavement. Environmental data such as temperature and rainfall can provide information on soils that are potentially susceptible to frost and construction problems during construction. Hence, the SoLAT database will be developed with consideration to the framework shown in Figure 1.

The Federal Highway Administration (FHWA) described two alternatives to data integration including data fusion and interoperable databases (2001). The former combines data from multiple sources into a single database, while the latter relate data from different databases through a series of queries. The merits of each of the two approaches will be evaluated based on the findings of the literature review and a complete review of existing WisDOT databases pertaining to transportation infrastructure.

Prior to the development of the database, the research team will share the knowledge acquired from the literature review with the designated WisDOT Technical Oversight Committee for the project to aid in the determination of the database structure, as well as data input and output formats that will be compatible with existing WisDOT databases. The research team will also meet with the Technical Oversight Committee once the database is designed, developed, and operable to demonstrate the database features prior to fully provisioning the database.

The database will be designed by Dr. Michael Rowe, a UWP Software Engineering Faculty member, with assistance from a UWP Software Engineering Research Assistant.

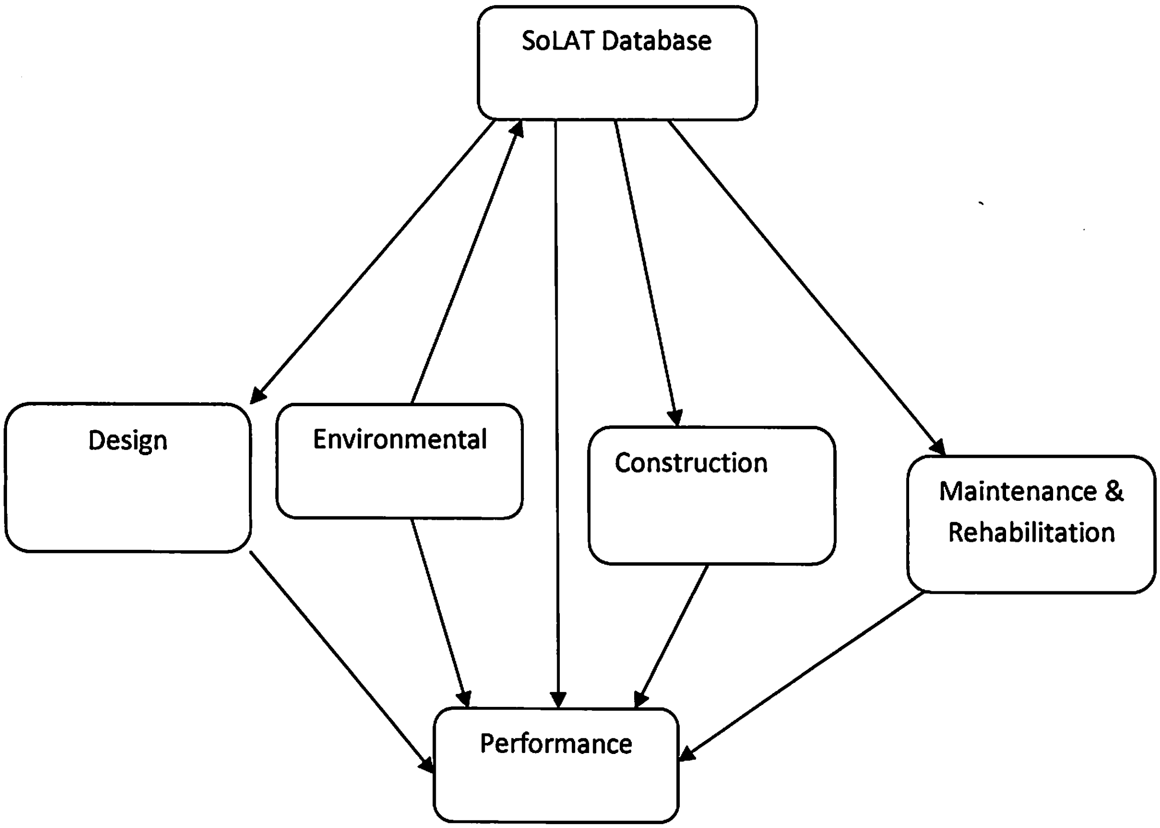


**Figure 1: Framework for Database Relationships**

Task 4: GIS Design and Linkage to Database

GIS is an information system that is designed to work with data referenced by spatial or geographic coordinates. It is an effective tool for integrating data from disparate databases that reside locally or at a remote location. Access to remote databases is made possible through the GIS database connection capabilities.

In GIS, a common data source includes a reference or base map, which enables specific queries about related data tables to be visualized on a dynamic map. The WisDOT Meta-Manager database system has geographic shape files covering the state trunk highway network for all five regions of Wisconsin. According to Javenkoski et al. (2005), these shape files have been produced in accordance with the requirements for the North American Datum of 1983 High Accuracy Reference Network (NAD83 HARN). Hence, geographic files from the Meta-Manager system will be considered potential sources for base maps. Once the base map is established, a soils survey map layer could be overlayed on top of the base map. The Natural Resources Conservation Service (NRCS) produces extensive electronic soil survey maps. Their applicability as the main soil overlay map will be explored using *ArcGIS* as the main GIS program. Once all map layers and corresponding attribute key fields compatible with other external databases have been developed, the maps will be linked with the databases and the system tested for functionality.

Task 5: Provisioning the Database

We estimate that approximately 10,000 laboratory test records will need to be entered into the database, with multiple lab test results included in each laboratory test record. Since the data entry does not require graduate level skills, the data will be entered into the database using UWP Research Assistants. Approximately 5 to 10 percent of the records entered into the database will be verified to insure proper and accurate entry of the data into the database. As indicated in the budget worksheet, we are estimating that 1700 hours will be required to enter the collected data into the database and to verify the data entry. We anticipate that we will hire two junior or senior-level Civil Engineering students part-time during the Spring and Fall 2011 semesters and two Civil Engineering students full-time during Summer 2011 to accomplish the data entry effort.

Task 6: Analysis of the Collected Data Using the Database

Once the data has been entered into the database, Task 6 will involve the analysis of the collected data to investigate for trends and correlations relating to soil types, geologic aspects, classifications, index and structural capacities, etc., including routine and sophisticated levels of test comparisons. The test results will also be compared to published values for similar soil types and testing. The first area of the state proposed to be analyzed is southeastern Wisconsin. The results of the analysis of the data in this area can be compared to the results presented in WHRP Report #0092-06-05, where Edil, et al (2009) compared basic laboratory test results with more sophisticated and in-situ test methods on soils in southeastern Wisconsin using WisDOT geotechnical data. Several additional areas of the state can also analyzed, with the results of the analysis being compared to the results presented in WHRP Report #0092-05-08, where Edil, et al (2007) evaluated the effects of physical characteristics and geologic factors on the shear strength of compacted sands from Wisconsin that are used as granular backfill for mechanically stabilized earth walls, reinforced soil slopes, and other transportation structures. The remaining areas of the state to be analyzed are those areas where statistically significant amounts of data are available, such as the Hwy 41 corridor in the Fox Valley.

The analysis of the collected data will be completed by Dr. Mark Meyers, PE, and Dr. Christina Curras. Dr. Meyers is the Chair and Associate Professor of Civil & Environmental Engineering at UWP and Dr. Curras is an Associate Professor of Civil & Environmental Engineering at UWP. Both Dr. Meyers and Dr. Curras are Geotechnical Engineers with the experience and qualifications required to analyze the collected data using the database.

Task 7: Reporting

Quarterly reports will be prepared and submitted as required by the WHRP. A comprehensive final report will be prepared which satisfies the program requirements, including an executive summary, problem statement, research background, study objectives, a description of the database and the features of the database, a summary of the data entered into the database, and the results of the analysis of the data in the database for various locations in Wisconsin. The database and all data, findings, and conclusions will be presented in a Final Project Report that will also discuss future additions to the database, proposals for inclusion of consultant work, necessary user training, and recommendations for the placement of and access to the database on the WisDOT system. A summary of the research results will be presented and the operation of the SoLAT database will be demonstrated.

## Anticipated Research Results and Implementation Plan

The final product resulting from this research project will be a fully provisioned electronic database of past WisDOT Geotechnical laboratory test data with an analysis of trends and correlations of the existing data. The SoLAT database will have capabilities allowing for the input of Geotechnical data resulting from future WisDOT and consultant subsurface investigations and laboratory testing programs and the development of trends and correlations of the soils data in the database for use in the planning and development stages of WisDOT projects, the refining of future subsurface investigation projects, and increasing the knowledge of representative types of soils throughout the state. The Final Report will include recommendations regarding the location of the database in the WisDOT computer system, operation of the database, and necessary user training.

## Project Schedule

The proposed project schedule is presented graphically in the bar chart in Exhibit 1 and detailed in Table 1.

**Table 1. UW-Platteville Project Schedule.**

| Task No. | Task Title | Start Date | Finish Date |
|---|---|---|---|
| 1 | Literature Search | Oct 1, 2010 | Dec 31, 2010 |
| 2 | Data Collection and Review | Oct 1, 2010 | Feb 28, 2011 |
| 3 | Database Development and Design | Dec 1, 2010 | Mar 31, 2011 |
| 4 | GIS Design and Linkage | Dec 1, 2010 | Mar 31, 2011 |
| 5 | Provisioning the Database | Apr 1, 2011 | Dec 31, 2011 |
| 6 | Analysis of Data | Jan 1, 2012 | Jun 30, 2012 |
| 7 | Draft Report | May 1, 2012 | Jun 30, 2012 |
| | TOC Review and Comment | July 1, 2012 | Aug 31, 2012 |
| | Final Report Submittal/Presentation | Aug 31, 2012 | Sep 30, 2012 |

## Budget Requirements

The research study scope presented herein satisfies the requirements stated in the RFP: to create an electronic database of WisDOT soil laboratory testing results that will be linked to a Geographic Information System (GIS) to allow for searching the records by spatial location and that can be easily searched and analyzed for use on future WisDOT projects for the purposes of planning cost-effective geotechnical explorations and providing geotechnical data for planning and early design stages. A breakdown of our cost estimate for this scope is presented in Exhibit 2 as information only. A review of Exhibit 2 indicates that the estimated cost of the study is $63,949. Other budget information required by WHRP is provided in Exhibits 3, 4, and 5; Exhibit 4 indicates the total project cost to be $63,951 (the difference between Exhibits 2 and 4 is due to rounding resulting from manual transfer of values from the spreadsheet used to create Exhibit 2 and Exhibit 4).

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| **Exhibit 1** | | | | | | | | | | | | |
| **UW-Platteville Schedule** | | | | | | | | | | | | |
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| | | | | | | **FY 2010-2011** | | | | | | |
| **Task** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **June** | **July** | **Aug** | **Sept** |
| | | | | | | | | | | | | |
| **Task 1: Literature Search** | | | | | | | | | | | | |
| **Task 2: Data Collection and Review** | | | | | | | | | | | | |
| **Task 3: Database Design/Development** | | | | | | | | | | | | |
| **Task 4: GIS Design and Linkage** | | | | | | | | | | | | |
| **Task 5: Provisioning the Data Base** | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | **FY 2011-2012** | | | | | | |
| | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **June** | **July** | **Aug** | **Sept** |
| **Phase 5: Provisioning the Database** | | | | | | | | | | | | |
| **Task 6: Data Analysis** | | | | | | | | | | | | |
| **Task 7: Report** | | | | | | | | | | | | |
| **TOC Review/Final Submittal/Presentation** | | | | | | | | | | | | |
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